Appendix G

DENDROCHRONOLOGY REPORT

BY

TREE RING LABORATORY
LAMONT-DOHERTY EARTH OBSERVATORY

Report to:

Hunter Research, Inc.
Historical Research Consultants

120 West State Street
Trenton, New Jersey 08608

from

Gordon C. Jacoby, PhD.
Burnt Hill Tree-Ring Consultants
P. O. Box 113
Raphine, Virginia 24472

Nicole Davi   Erika Mashig
Tree-Ring Laboratory
Lamont-Doherty Earth Observatory
61 Route 9 W
Palisades, New York 10964

June 2003

additional contact information

Dr. Gordon C. Jacoby, Director Emeritus
Tree-Ring Laboratory
Lamont-Doherty Earth Observatory
61 Route 9 W
Palisades, New York 10964
845 365 8616   845 365 8152 fax
email: druid@ldeo.columbia.edu
http://www.ldeo.columbia.edu/trl/

Background for dating of historical structures using tree-ring analysis:

Dendrochronology is the science of dating and studying annual growth layers of trees and wood. (after Fritts 1976). Dating is the crucial element of such studies because interpretations are based on the absolute calendar or relative dating of the annual layers or rings of the wood samples. For the purpose of dating historical structures, the dating of the outermost ring or partial ring determines the date after which the structure may have been built. Although a structure may have been built after this date due to time of seasoning, or reuse of timbers, it cannot have been built before this date.

When dating historical structures, samples are taken by coring timbers or cutting sections or wedges from the timbers. During this sampling the outermost ring or partial ring must be obtained intact in order to determine the exact date the tree was felled. Experienced judgement must be used to determine if an outer ring or underbark wood is present. This can be evidenced by a wane or waney edge being present. Presence of bark reinforces the interpretation. Also there must be enough rings present to produce a unique pattern of variations through time for the sample to be crossdated with other samples whose dates have been previously determined. This usually calls for 50 to 80 rings at a minimum and varies depending on the amplitude of the year to year variations in ring width.

Each individual tree and wood sample has unique variations that record the growth patterns of that sample or radius of a section. It is the communal variation that a group of trees have that facilitates the crossdating. The most common influence causing a similar communal variation is climate, which pervades a site or region. The unique variations in each tree, sample, or radius are "noise" and the communal tree variation is what corresponds from sample to sample. The noise in the information from individual samples necessitates the use of multiple samples or replication. Therefore there must be several samples tested to develop the communal signal and demonstrate an identical result from different samples.

The communal variation is crossdated by pattern matching between samples and previously dated ring-width series. The pattern matching may be achieved by graphical or statistical means, or by direct comparisons of samples. The various techniques of statistical crossdating serve to make the tree-ring scientist more efficient. However, ultimately the graphical matching performed by a skilled dendrochronologist is the final test or verification of correct crossdating (Douglas 1919 and Pilcher 1990).

Tweed's Tavern:

Tweeds Tavern, built roughly 200 years ago, is located on Limestone Road, Hokkessin Delaware. The structure was originally located 0.2 miles south on the intersection of Limestone and Valley roads, but was moved in June 2000 due to the widening of the road.

On 1 April 2003 a dendrochronological sampling of the Tweeds Tavern structure was conducted. Samples were taken from 13 oak beams in the structure, 9 samples were sections and 4 were core samples. **Table 1** lists the samples taken. The samples were sanded and polished so that each individual cell in each ring of each sample was visible under microscopic examination. Each core sample was mounted in a special mounting stick to give it structural support during the sanding and polishing process. Ring widths were measured on two radii of each section and ring widths were measured on one 12-mm diameter core sample. All the ring widths were measured to a precision of +/- 0.001 mm. Another 12-mm core had the outer sapwood rings damaged by powder post beetles and some outer rings were crumbled and damaged during the coring process so there was not an intact sample produced.

Two 5-mm. diameter core samples were not useful for analysis because they came out in many pieces and were twisted. This is often the result when using the 5-mm corers due to the brittleness of the old dried out wood. However, on other occasions we have recovered good samples using the 5-mm. corers. It is useful to test the usefulness of 5-m. cores in each structure because the smaller diameter corers make a smaller hole in a beam and more can be collected in a shorter time.

The standard process involves crossdating between radii of the same section, next crossdating is done between different samples from the same structural portion or "build", and finally a master series is developed from the best samples from the build. The sample data were processed through a program named COFECHA (Holmes 1983) which is for preliminary dating and quality control in processing tree-ring samples and data. COFECHA develops a master series by filtering out low frequency variations and making an average index from the measurements of all the individual trees. It also shows the correlations between each sample and allows the identification of samples or radii with anomalous growth. The master series is of better quality if anomalous samples are excluded. In this case the radius "a" from section 10 had a disturbed growth pattern and introduced excessive "noise" into the master series. Therefore it was excluded from the master series.

In a preliminary analysis, this master series was compared to dated master series or standardized oak chronologies from the region around northern Delaware. The source area of these series used to test for crossdating extended from northern Virginia to southern New York state. Tentative crossdating was achieved with a composite tree-ring series developed previously from samples obtained in Philadelphia from historic structures. As expected the dating with more distant series was weak to nonexistent. The data from Tweed's Tavern were then processed through a program called ARSTAN (Cook 1985) which process tree ring data to remove any trends due to the aging of the tree and quantitatively determines the communal variation for a tree-ring-width data set. The ARSTAN processing uses statistical techniques to reduce the "noise" and improve the communal signal from the tree-ring data set. The resulting series is called a chronology. **Figure 1** shows a plot of the Tweed's Tavern chronology and the Philadelphia master chronology.

In addition to the measured ring widths one must also examine the outer ring of each sample and radius for any evidence of partial growth the following year. Outer partial rings are not measured. If there is no evidence of partial growth then the tree must have been cut down between the end of the season of cambial cell division for one year and before the initiation of cambial cell division the following year. Many wood cutters preferred to cut down trees in the early spring when growth processes cause the bond between wood and bark to be weak and the debarking is easier. In the case of oaks, which are ring porous, the pores or earlywood vessels are formed in spring and the dense fibrous latewood is formed in the summer. Evidence of partial growth established the year and even season of tree cutting.

Results:

The results of the analyses are shown in **Table 2**. The table shows the year of the dated outer rings, presence or absence of growth the following year, and the resulting date of tree cutting. Two of the samples were loose pieces of wood, not integral parts of the structure. These types of samples are useful as they increase the data base for analysis even though they cannot be used for the actual dating of the structure. Five of the samples built into the structure are from trees that were cut in late 1795 or early 1796. Two of the five were cut in the spring of 1796. Three of the trees were cut down in spring of 1797.

References Cited:

Cook, E.R. (1985). *A time series analysis approach to tree-ring standardization*. Ph.D. thesis, University of Arizona, Tucson.

Douglass, A.E. (1919). Climatic Cycles and Tree Growth: Vol. I: A Study of theAnnual Rings of Trees in Relation to Climate and Solar Activity. Carnegie Institute of Washington Publication 289: 1-127.

Fritts, H. C. (1976). *Tree Rings and Climate*. London: Academic Press.

Holmes, R.L., (1983). Computer-assisted quality control in tree-ring dating and measurement. *Tree-Ring Bulletin* **44**, 69-75

Pilcher, J.R. (1990). Sample preparation, cross-dating, and measurement. In: E.R. Cook and L.A. Kairiukstis, eds., Methods of Dendrochronology: Applications in the Environmental Sciences. International Institute for Applied Systems Analysis, Kluwer Academic Publishers, Boston, MA: 40-51.

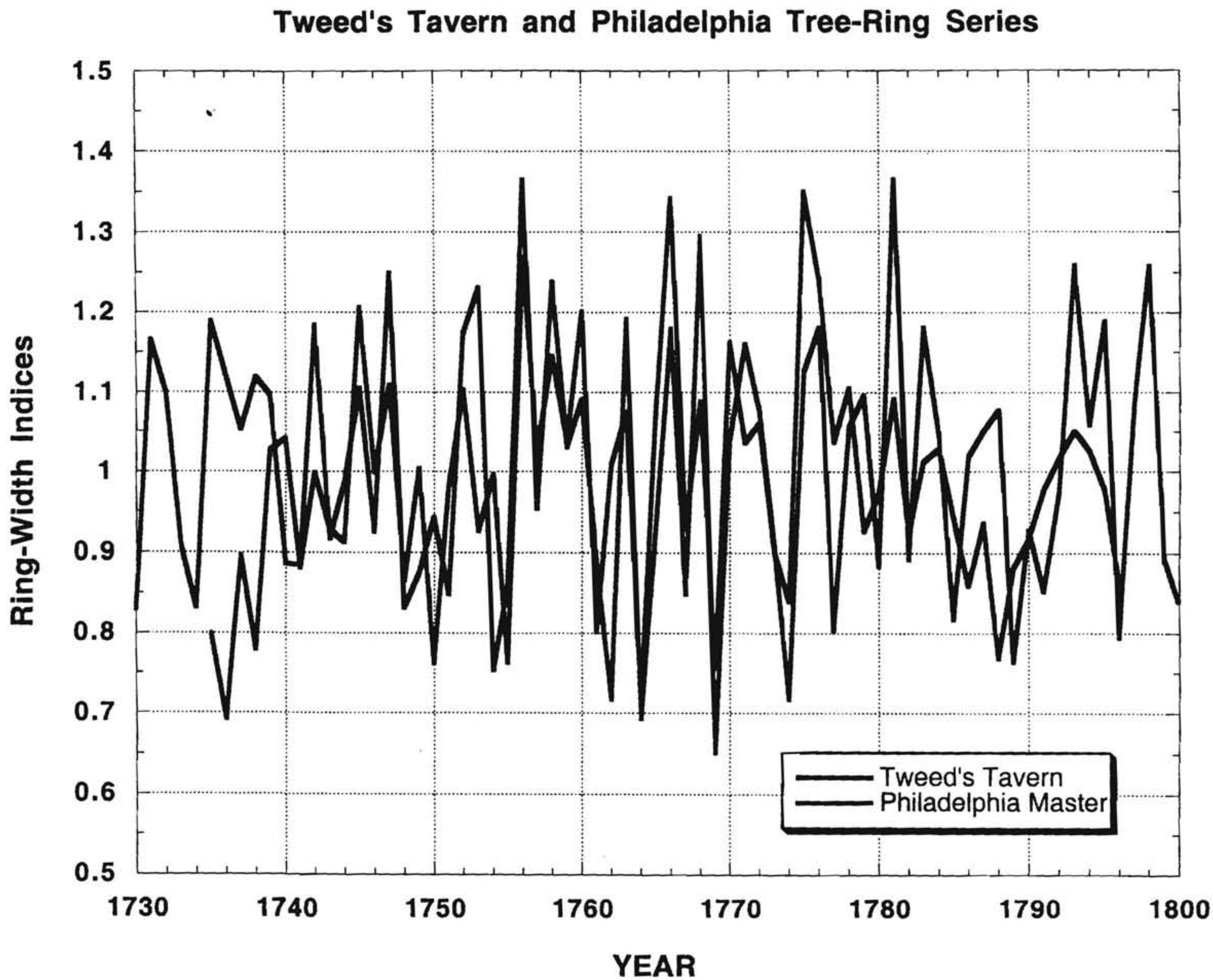
Tables and Figure:

Table 1: List of Samples from Tweed's Tavern (all oak)

ID no.	Type	Comment
TT01	section	float*
TT02	section	
TT03	section	
TT04	section	
TT05	section	
TT06	12-mm. core	
TT07	5-mm. core	not useful, twisted & in pieces
TT08	section	float*
TT09	section	
TT10	section	
TT11	12-mm. core	not useful, beetle damage of outer rings
TT12	section	
TT13	5-mm. core	not useful, twisted & in pieces

* float means the piece was not structurally part of the building

Figure 1: Plot of ring-width indices from the standardized chronologies representing samples from Tweed's Tavern and Philadelphia Master collection. The match shows excellent crossdating with the occasional shift that often occurs in such plots due to unique properties of each series caused by ecological and other nonclimatic factors.



Tweed's Tavern and Philadelphia Tree-Ring Series
Ring-Width Indices
1.5
1.4
1.3
1.2
1.1
1
0.9
0.8
0.7
0.6
0.5
1730
1740
1750
1760
1770
1780
1790
1800
YEAR
Tweed's Tavern
Philadelphia Master

Table 2: DATED TIME PLOT OF TREE-RING SERIES: Tweed's Tavern

1700 1800 1900 2000	Ident	Seq	Beg year	End year	Yrs	Earlywood Vessels	Cutting Year	
. <====>.	TT01a	1	1740	1794	55	x	1794-95	float*
. <====>.	TT01b	2	1740	1794	55	x		
. <=====>.	TT02a	3	1733	1795	63	y	1796	
. <=====>.	TT02b	4	1733	1795	63	y		
. <====>.	TT03a	5	1740	1795	56	x	1795-96	
. <====>.	TT03b	6	1740	1795	56	x		
. <=====>.	TT04a	7	1735	1796	62	y	1797	
. <=====>.	TT04b	8	1735	1796	62	y		
. <=====>.	TT05a	9	1737	1795	59	y	1796	
. <=====>.	TT05b	10	1737	1795	59	y		
. <====>.	TT06	11	1742	1796	55	y	1797	core
. <====>.	TT08a	12	1746	1790	45	x	1790-91	float*
. <====>.	TT08b	13	1746	1790	45	x		
. <=====>.	TT09a	14	1738	1795	58	x	1795-96	
. <=====>.	TT09b	15	1738	1795	58	x		
. <=====>.	TT10b	16	1737	1795	59	x	1795-96	
. <===>.	TT12a	17	1750	1794	45	decayed		
. <===>.	TT12b	18	1750	1796	47	y	1797	

* float means the piece was not structurally part of the building